THE WEATHER AND CIRCULATION OF MAY 1960

Including a Discussion of the Unusual Retrogression of 5-Day Mean Polar Vortices

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1. MEAN CIRCULATION

The monthly mean circulation at 700 mb. for May 1960 (fig. 1) was characterized by strong blocking over much of the higher latitudes of the Northern Hemisphere. In terms of 700-mb. height anomaly, the principal centers of blocking were located over eastern Canada (+320 ft.) and northern Siberia (+370 ft.) with another, somewhat weaker, center over southwestern Alaska (+180 ft.). The effect of this blocking on the mid-latitude planetary circulation was to produce a pattern of truncated trough-ridge systems with rather short wave spacings. The exception to this was in the Pacific where the weaker Alaskan block was associated with a simple zonal pattern and full-latitude mid-Pacific trough (fig. 1).

A further effect of the blocking was to displace the mid-tropospheric westerlies at 700 mb. south of their normal position over most of the western part of the Northern Hemisphere (fig. 2A). The greatest displacement of the zone of maximum west winds was over the eastern United States and western Atlantic, the area south of the Canadian block. Wind speeds at 700 mb. were as much as 7 m.p.s. below normal near Nova Scotia (fig. 2B). Another area of subnormal wind speeds was in the Gulf of Alaska, a manifestation of the Alaskan block. The fastest wind speeds, up to 6 m.p.s. above normal, were found in the eastern Pacific.

The effects of blocking at 700 mb. were also apparent on the monthly mean sea level chart for May (fig. 3). Pressures averaged well above normal over much of the higher latitudes, with centers of greatest departure in northern Siberia (+14 mb.), the western Pacific (+8 mb.), and eastern Canada (+7 mb.). Sea level pressures and 700-mb. heights were both well below normal across most of the United States and Atlantic (figs. 1 and 3), a further indication of the strong blocking in eastern Canada.

2. AVERAGE UNITED STATES WEATHER

May was a rather cool month over much of the contiguous United States. Temperatures were generally below normal, except in the central and southern Rocky Mountain States, the Northern Plains, along the California coast, and in the Northeast, where above normal temperatures prevailed (fig. 4A). The greatest negative departures were observed in the Pacific Northwest where temperatures averaged 4° F. below normal. Greatest positive departures were found in the Northeast where Caribou, Maine, reported 9° F. above normal for May. No monthly mean temperature records were established, one reason being that May had two relatively well-defined temperature regimes (see section 3).

The May temperature pattern was well related to the mean circulation pattern. In general the cool weather was associated with below normal 700-mb. heights and westerlies well south of normal across the United States (figs. 1 and 2). The thickness of the layer between 1000 mb. and 700 mb. was also below normal over most of the Nation (fig. 5). The warmth in the Northeast was related to the strong ridge over eastern Canada and associated southeasterly anomalous flow at the surface (fig. 3) and aloft (fig. 1). Thickness values were also above normal in this area.

Figure 4B shows the total precipitation and figure 4C the percentage of normal precipitation for May 1960. Near record amounts fell in the Pacific Northwest where some areas received more than twice their normal totals for the month. Heaviest amounts fell along the coast and at the higher elevations. Mt. Shasta, Calif., with a record dating back to 1888, recorded its greatest snowfall for May, while Stampede Pass, Wash., set a new May record for total precipitation with 9.12 inches.

Precipitation was also heavy in portions of the Mid-West and Middle Atlantic States (figs. 4B, 4C). La Crosse, Wis., experienced its wettest May since observations began in 1873. Near record amounts fell in Green Bay, Wis., Marquette, Mich., and Tulsa, Okla. Areas receiving less than half their normal totals for May were Wyoming, northern and eastern Texas, northwestern Georgia, and central Florida (fig. 4C).

Precipitation, as is usually the case during the warm season, was not too well related to the mean circulation. A strong relationship existed in the Pacific Northwest, however, where cool, wet weather accompanied stronger than normal southwesterly flow from the trough in the eastern Pacific (figs. 1, 2B). Furthermore, the heaviest precipitation fell close to or just north of the zone of maximum wind at 700 mb. (figs. 2, 4B). The band of

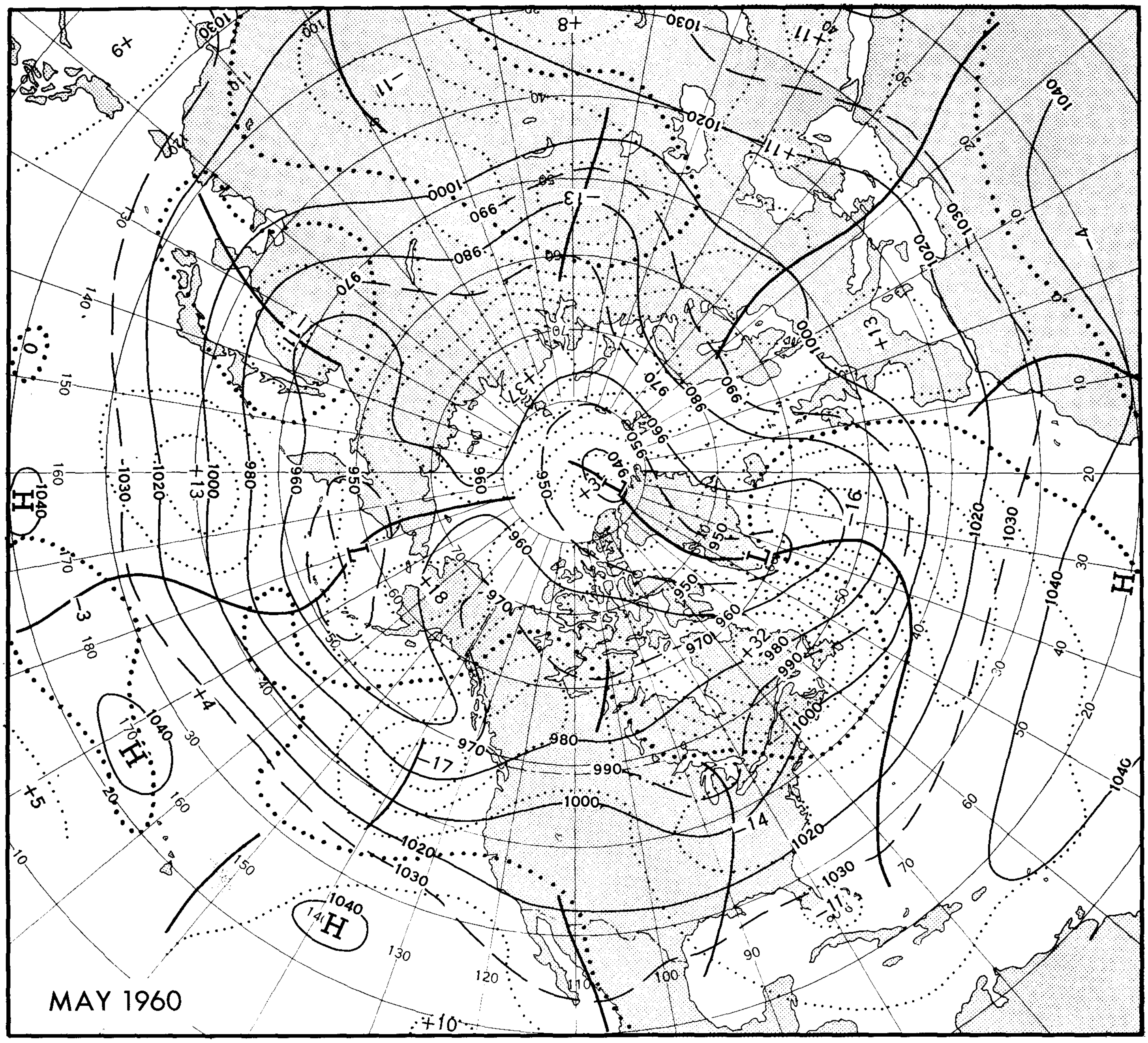


FIGURE 1.—Mean 700-mb. contours (solid) and height departures from normal (dotted), both in tens of feet, for May 1960. Blocking was a prominent feature of the circulation.

precipitation stretching from Nevada to New Mexico, with lower percentages to the north and south (figs. 4B, 4C), appears to bear some relationship to the difluent circulation pattern at 700 mb. (fig. 1). Most of the precipitation in the eastern half of the United States can be associated with the deep mean trough over that area. It is interesting to note, however, that the smaller amounts (and percentages) were observed in the trough itself and generally in the area defined by the −100-ft. departure from normal isoline (figs. 1, 4B, 4C). Amounts were much greater in the surrounding area.

Alaska was unseasonably warm during May with mostly subnormal amounts of precipitation (fig. 4). Both Fairbanks and Juneau experienced their warmest Mays of record, while Yakutat reported its driest May. This warm, dry regime was associated with a strong ridge, above normal 700-mb. heights, and positive thickness in the layer 1000 mb. to 700 mb. (figs. 1, 5).

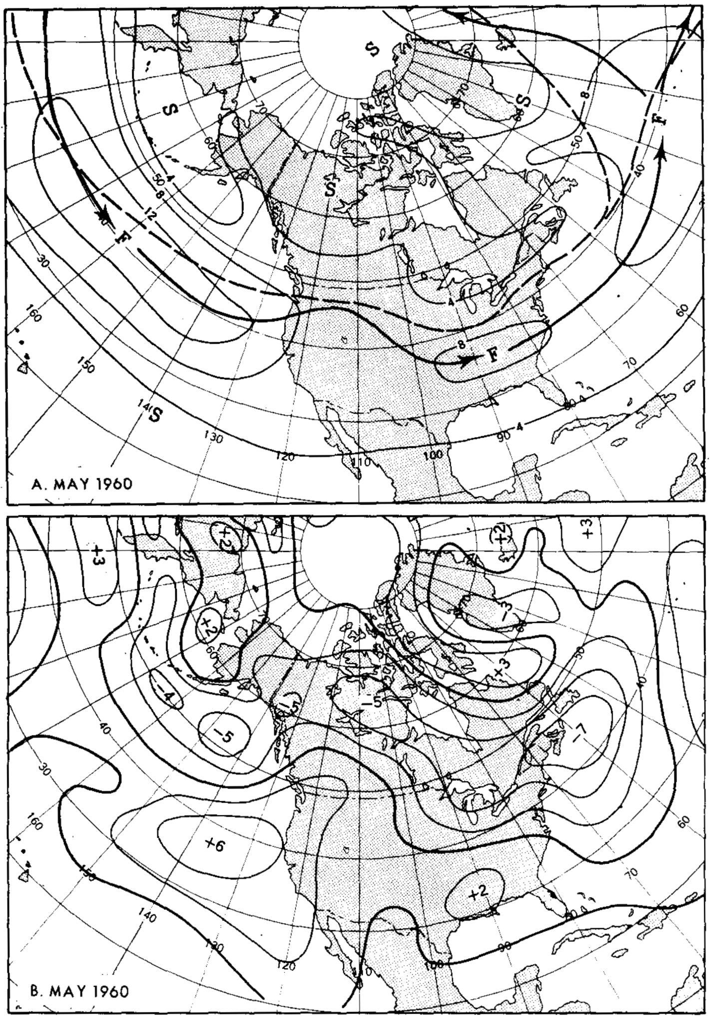
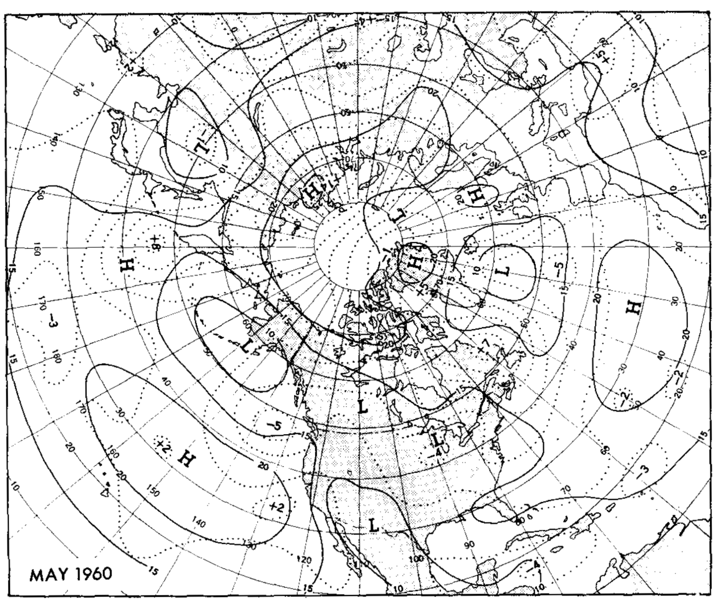


FIGURE 2.—(A) Mean 700-mb. isotachs and (B) departure from monthly normal wind speed (both in meters per second) for May 1960. Solid arrows in (A) indicate axes of primary west wind maxima with the normal position dashed. Because of blocking, the westerlies were displaced to lower latitudes.



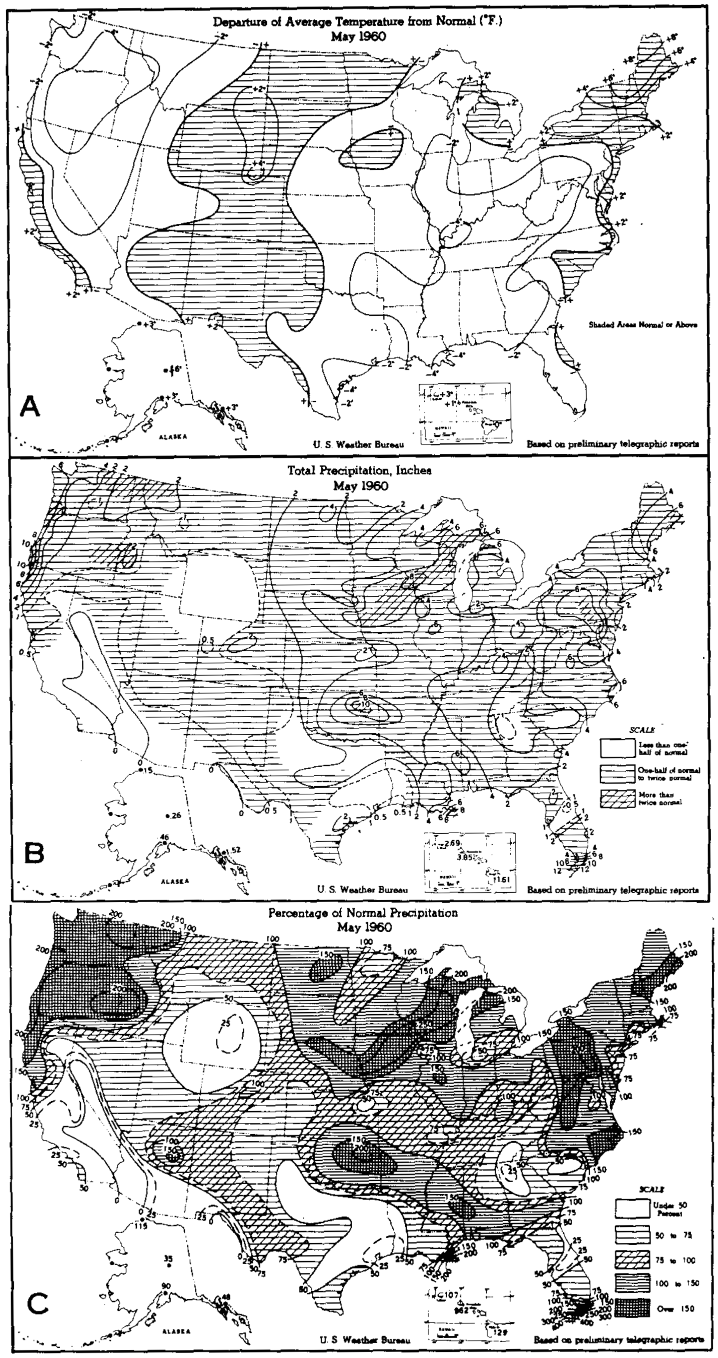


FIGURE 4.—(A) Departure of average temperature from normal (°F.) for May 1960. (B) Total precipitation (inches) for May 1960. (C) Percentage of normal precipitation for May 1960. (From [1].)

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FIGURE 3.—Mean sea level isobars (solid) and their departures from normal (dotted), both in millibars, for May 1960. Excess of pressure at high latitudes and deficit at low latitudes were associated with high-latitude blocking.

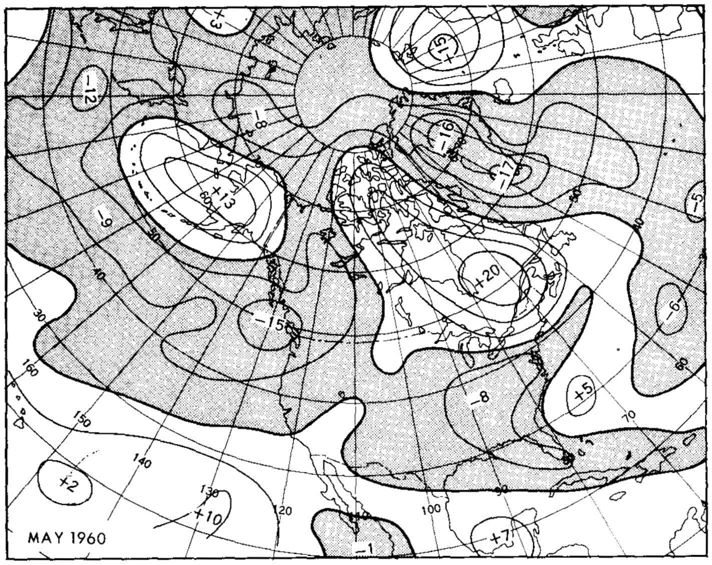


FIGURE 5.—Mean thickness (1000–700 mb.) departure from normal (tens of feet) for May 1960. Below normal thickness over much of the contiguous United States was associated with generally cool surface temperature.

An unusual event occurred in the Hawaiian Islands when the first thunderstorms ever observed during May were reported at Honolulu. They accompanied the passage of a 500-mb. Low over the Islands and were responsible for a new May precipitation record at Honolulu.

3. TWO CONTRASTING WEATHER AND CIRCULATION REGIMES

May's weather and circulation was composed of two rather well-defined regimes, particularly with respect to temperature and circulation. In figure 6 are shown the half-month mean circulation patterns at 700 mb. for May 1960, along with the height changes between the two periods, while figures 7 and 8 show the corresponding temperature anomaly and total precipitation. During the first half of May a deep trough was observed over the eastern United States, while ridge conditions predominated in the West (fig. 6A). Strong blocking existed in eastern Canada and helped maintain the westerlies well south of their normal position across eastern North America. The trough was associated with temperatures well below normal over most of the eastern United States, as much as 8° F. in Kentucky and Tennessee (fig. 7A). Only the extreme Northeast, under the influence of a ridge and positive height anomalies, was warm.

Much of the cool weather was the result of a single storm system which developed in the Southwest about May 4. This storm brought heavy rains, hail, and high winds to many sections, tornadoes in Oklahoma and Arkansas, and heavy snowfall in Wisconsin, Upper Michigan, and the eastern slopes of the Colorado Rockies. Dubuque, Iowa, reported 4.38 inches of rain in a 24-hour period on the 5th and 6th, the largest amount in a similar period for any May. Snowfall amounts of 3 to 5 inches were common in much of Wisconsin and Upper Michigan. At Oklahoma City, Okla., a wind speed of 72 m.p.h. exceeded the previous record for any May. As the storm moved slowly northeastward, it became blocked by a large high pressure area over Hudson Bay. Both high and low pressure systems remained nearly stationary for the period May 7–13. Cold air moving southward to the rear of the storm resulted in numerous temperature records being established for the lowest reading so late in the spring. Some of these are listed in table 1.

TABLE 1.—*Late spring minimum temperature records established during May 1960*

Station	Date	Temperature (° F.)
Chattanooga, Tenn.	9	*35
Madison, Wis.	12	27
Springfield, Mo.	12	30
Abilene, Tex.	12	41
Shreveport, La.	12	42
New Orleans, La.	13	*41
Meridian, Miss.	13	*38
Montgomery, Ala.	13	*42
Apalachicola, Fla.	13	*50
Macon, Ga.	13	42
Greenville, S.C.	13	39
Raleigh, N.C.	13	40

*Also a record low for any May.

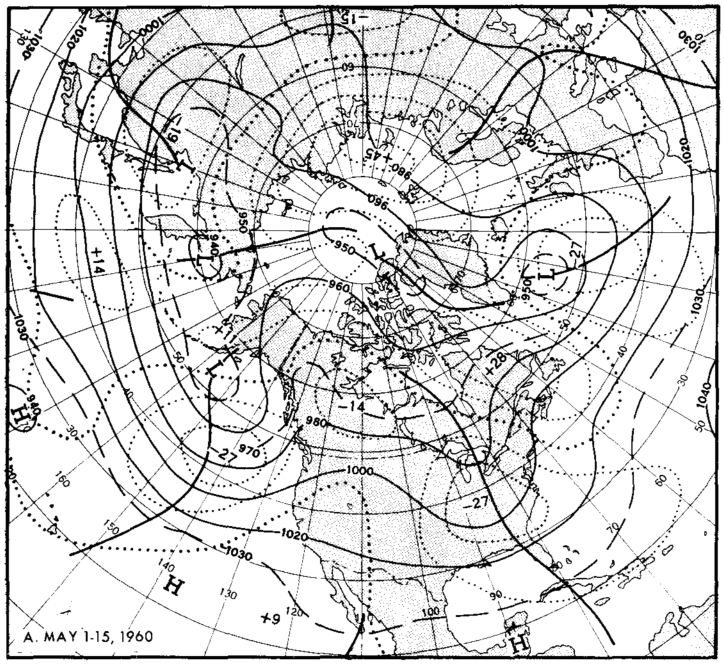
While the East was experiencing temperatures more characteristic of March, the West was enjoying considerably warmer weather during the first half of May (fig. 7A). Much of this warmth occurred during the period May 11–13 when many cities established daily maximum temperature records. In addition, several stations set new maximum temperature records for occurrence so early in the year, as shown in table 2. This extreme warmth, coupled with record cold in the East, resulted from a large-amplitude ridge-trough system.

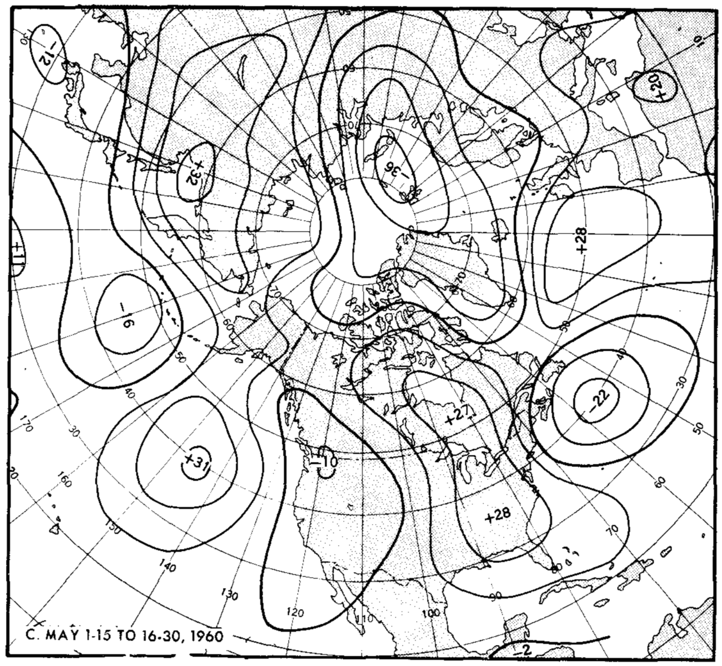
The circulation reversal which occurred near mid-month was primarily related to establishment of a new trough in the mid-Pacific (fig. 6). This new development in the mid-tropospheric circulation effectively shortened the wavelength between the planetary waves, thus forcing eastward the downstream trough-ridge systems. As a result the trough over eastern North America was replaced by a ridge, while the opposite change occurred in the West. This transition in the mean 700-mb. circulation at mid-month can, perhaps, best be seen by reference to figure 6C, which shows the height changes between the two halves of May. The rather uniform spacing of change centers in

TABLE 2.—*Early season maximum temperature records established during May 1960*

Station	Date	Temperature (° F.)
Pocatello, Idaho	11	90
Helena, Mont.	12	88
Billings, Mont.	12	94
Sheridan, Wyo.	12	*95
Salt Lake City, Utah	12	92
Winslow, Ariz.	12	94

*Ties record for May.





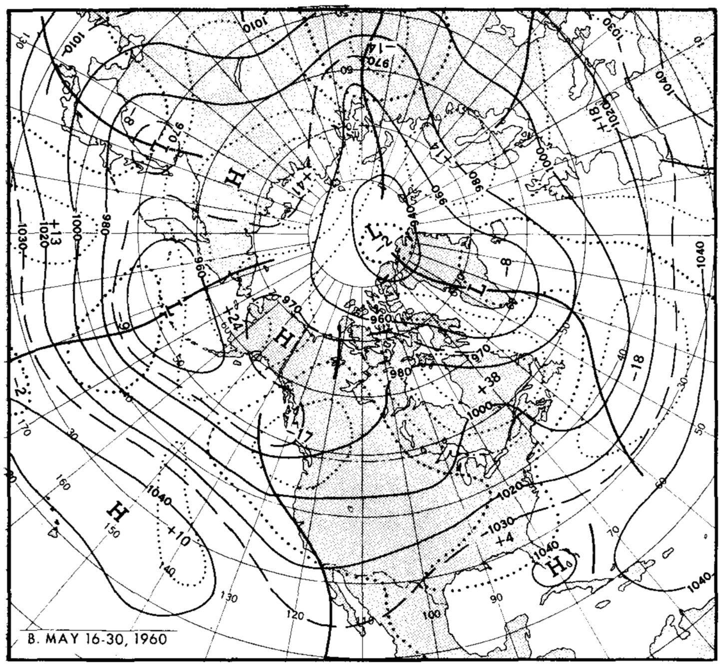


Figure 6.—Fifteen-day mean 700-mb. height contours (solid) and departures from normal (dotted) (both in tens of feet) for (A) May 1–15, 1960, and (B) May 16–30, 1960. (C) Height change (tens of feet) from (A) to (B). Circulation reversal over North America was accompanied by a change in temperature regimes in the United States.

the western part of the hemisphere reflects quite well the complete circulation reversal there.

These changes in circulation were accompanied by an equally pronounced reversal of temperature regimes in the United States (fig. 7). Most of the East experienced a rapid change to warmer, while the West reverted to a cold regime. Because of the persistence of blocking and above normal 700-mb. heights in eastern Canada, the Northeast remained warm for the entire month. Caribou, Maine, established several daily maximum temperature records, and a reading of 91° F. on the 29th was the highest temperature ever observed there so early in the season. Elsewhere in the East the unseasonably warm weather was generally not of a record-breaking nature.

Cool weather in the West was the result of frequent intrusions of polar Pacific air masses associated with the mean trough and below normal 700-mb. heights (figs. 6B, 7B). Temperatures averaged as much as 8° F. below normal in Oregon. The strongest of these cold intrusions brought the lowest temperatures ever observed so late in the spring to many areas of the Far West. Some of these are listed in table 3.

The precipitation pattern (fig. 8) was not as well related to the mid-month circulation reversal as was temperature. This is not unusual in view of the discontinuous and sporadic nature of precipitation, especially during the warm season. In general, however, the area from the Gulf States to New England received somewhat less precipitation during the latter half of May, while the Plains States and Mississippi Valley received more (fig. 8). Heavier amounts also fell along the north Pacific coast as

Table 3.—*Late Spring minimum temperature records established during May 1960*

Station	Date	Temperature (° F.)
Grand Junction, Colo	19	34
Salt Lake City, Utah	19	31
Albuquerque, N.Mex	20	37
Red Bluff, Calif	22	40
Boise, Idaho	22	28
Portland, Oreg	22	33
Yakima, Wash	22	27
Missoula, Mont	23	26

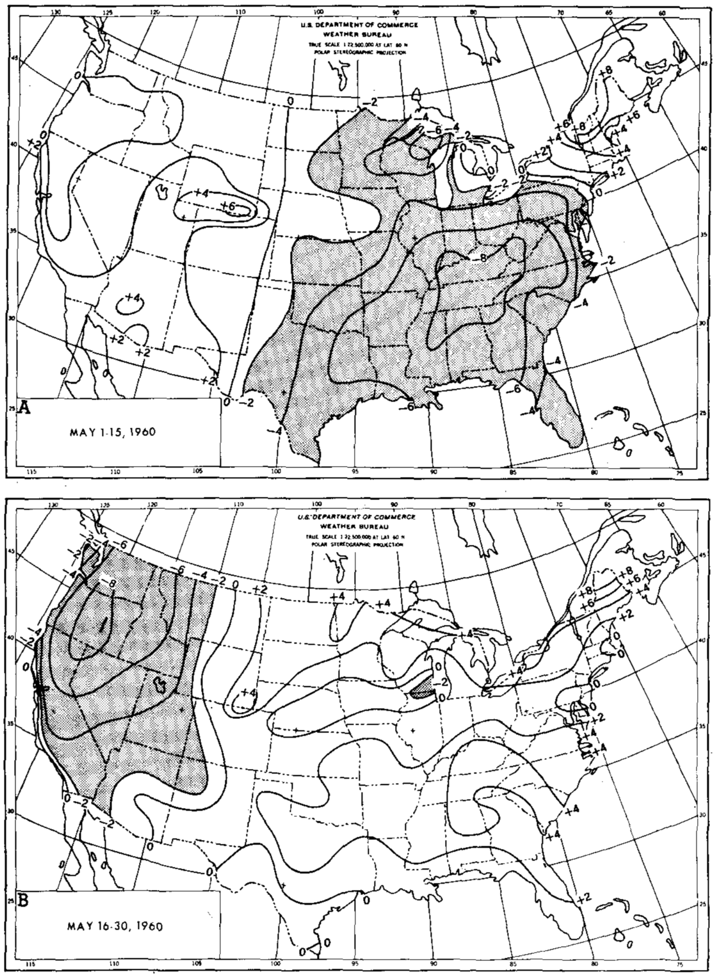


FIGURE 7.—Departure of average temperature from normal (° F.) for (A) May 1–15, 1960, and (B) May 16–30, 1960. Areas of negative departure greater than 2 are stippled. Sharp tempera ture reversal is evident.

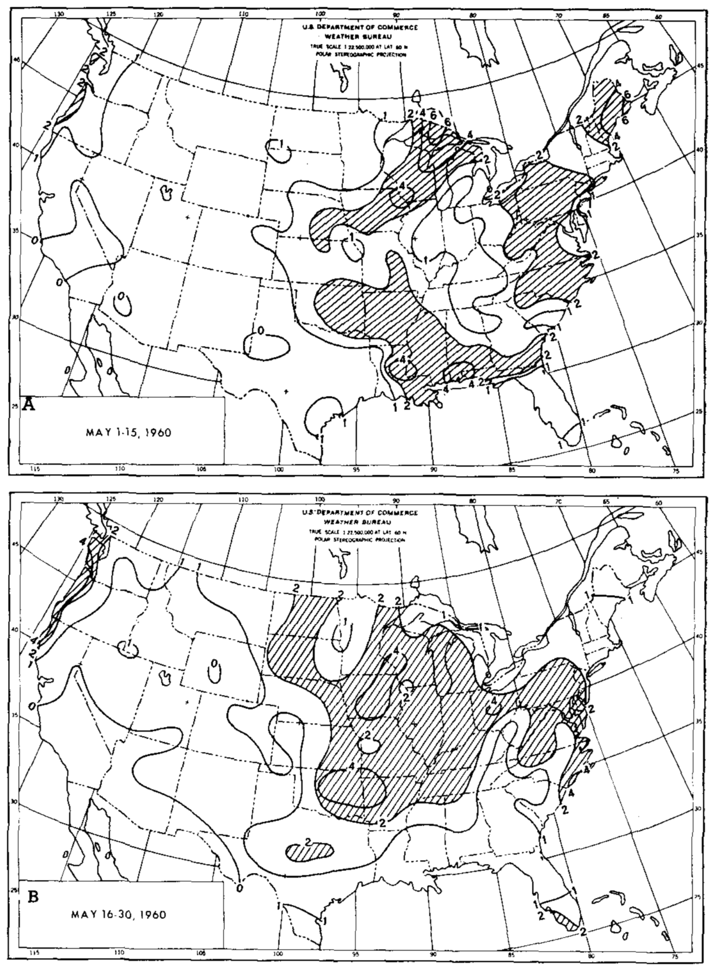


FIGURE 8.—Observed precipitation (approximate) in inches for (A) May 1–15, 1960, and (B) May 16–30, 1960. Areas of amounts greater than 2 inches are hatched.

the mean trough in the eastern Pacific moved toward the coast (figs. 6, 8).

Weather and circulation reversals of this type are not unusual and have been discussed in previous articles of this series. In fact, this is the second consecutive month that this has occurred. Thus, during April-May 1960 a half-month periodicity was observed, primarily in the temperature and circulation patterns in the United States. However, while April [2] was predominantly a warm month, May was cool. This was because the zonal westerlies across the United States were much farther south in May.

4. RETROGRESSION OF 5-DAY MEAN POLAR CYCLONIC AND ANTICYCLONIC VORTICES

During May 1960 the polar circulation of the Northern Hemisphere was dominated primarily by two 5-day mean cells, one an anticyclone and the other a cyclone. In figure 9 are shown the tracks of these high and low cells at 700 mb. and sea level, as prepared from 5-day mean charts drawn thrice-weekly in the Extended Forecast Section. Positions shown are one week apart and are plotted on the middle day of the 5-day period.

One striking feature of these tracks is the continuous retrogression of the vortices around the pole. Only the path of the upper-level anticyclone appeared to be discontinuous over the Canadian Arctic near mid-month (fig. 9A). At that time the major 700-mb. High departed from its polar orbit and moved southward into eastern Canada. At the same time, however, the primary surface high pressure area continued in its circumpolar path, although a break-off High (fig. 9C) did move southward in association with the upper-level center (fig. 9A). An inspection of daily Northern Hemisphere sea level charts for May also disclosed the predominantly continuous nature of the retrogression of the surface cells.

A complete physical explanation of the unusually persistent retrogression of these mean polar vortices cannot be attempted here. However, a brief study was made of how well the polar trough was predicted by the daily and

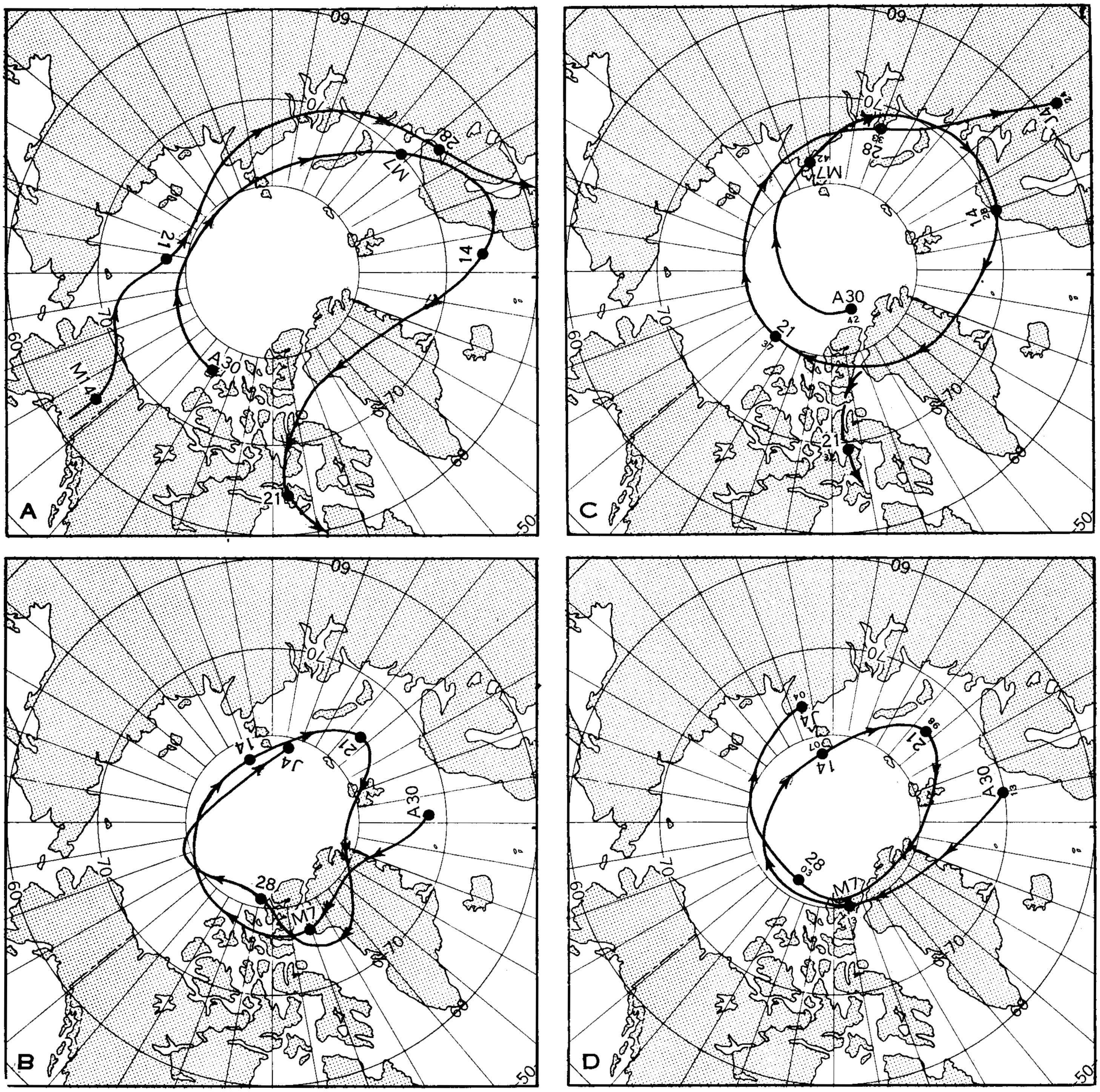


FIGURE 9.—Tracks of 5-day mean polar vortices during May 1960 at 700 mb. for (A) anticyclone, (B) cyclone, and at sea level for (C) anticyclone, (D) cyclone. Top number is middle day of period; lower number on (C) and (D), intensity of center (millibars). Continuous retrogression of high-latitude vortices around the pole was the most unusual circulation feature of May.

5-day mean barotropic charts now in use in the Extended Forecast Section [3]. Results showed that in general the direction of motion (retrogression) was correctly forecast, but the forecast magnitude was only about half the observed motion. This would indicate that the principle of conservation of absolute vorticity was applicable, at least qualitatively.

Variations in the strength of the polar zonal circulation were quite marked as a result of rotation of these systems around the pole. To illustrate this, figure 10 shows the

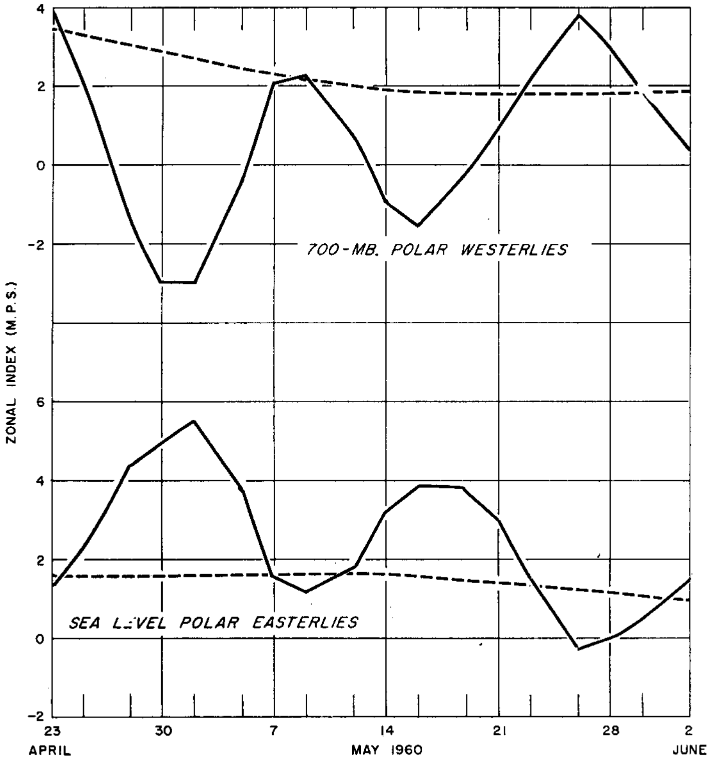


FIGURE 10.—Time variation of 700-mb. polar westerlies (top) and sea level polar easterlies (bottom) (both in meters per second) over the western sector of the Northern Hemisphere between latitudes 55° and 70° N. Solid lines connect 5-day mean index values (plotted at middle of 5-day period and computed thrice weekly), and dashed lines show variation of corresponding normal indices. The polar circulation featured two index cycles during May 1960.

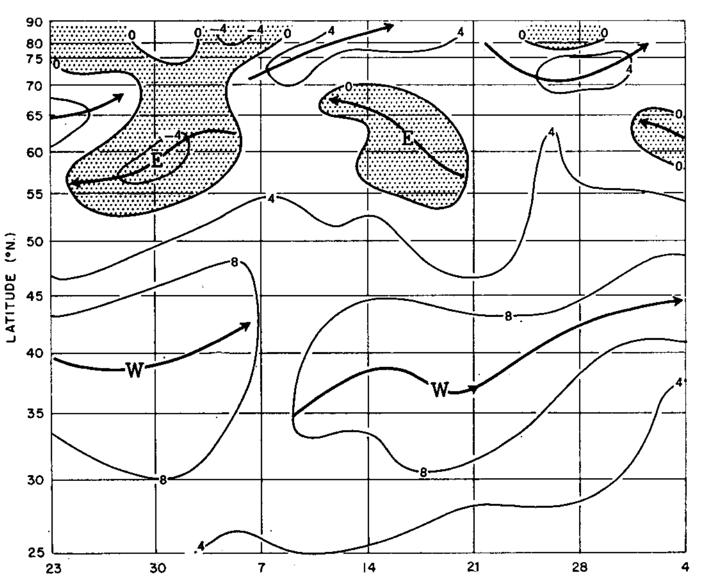


FIGURE 11.—Time-latitude section of 5-day mean zonal wind components at 700 mb. averaged over the western part of the Northern Hemisphere. Isotachs are in meters per second with easterly winds stippled. Primary wind axes (both easterly and westerly) are shown as solid arrows. The alternating periods of net easterly and westerly flow at the higher latitudes reflect the periodicity in the polar circulation.

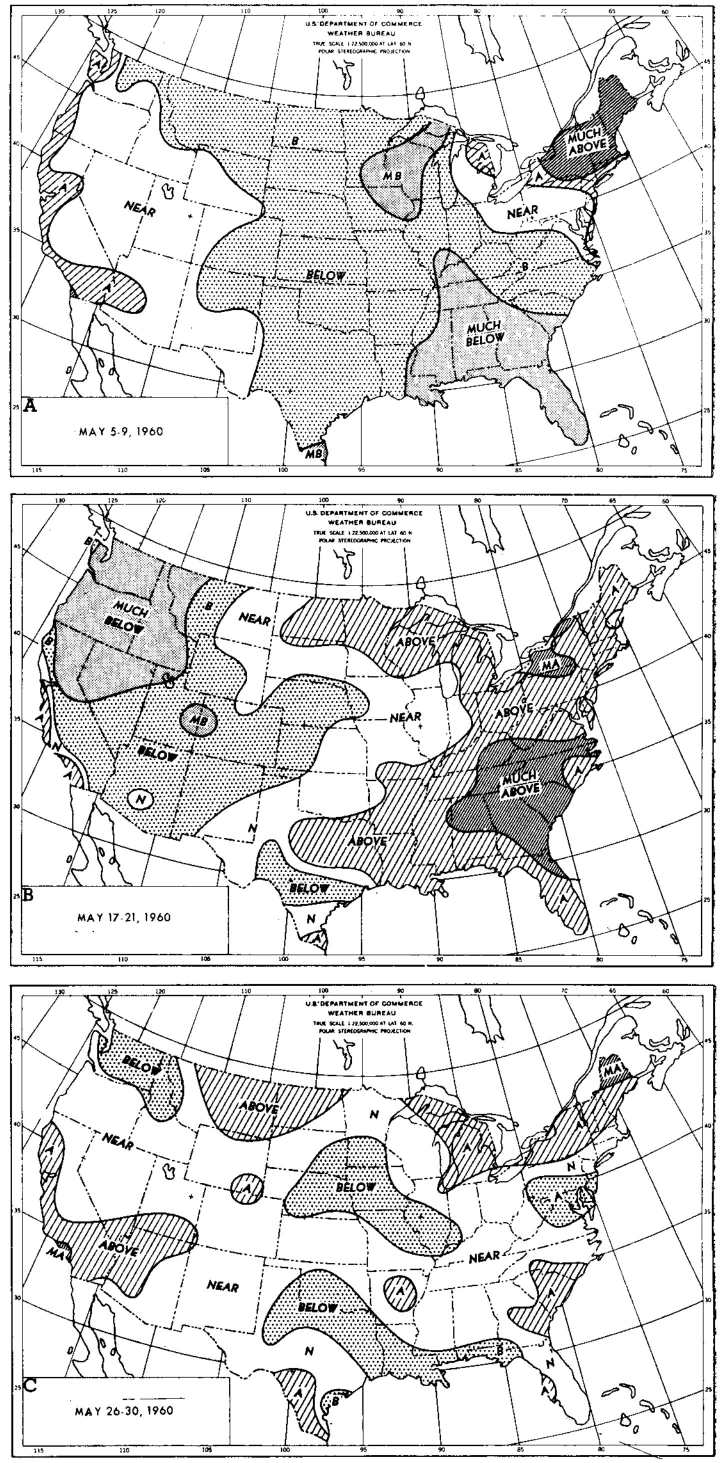
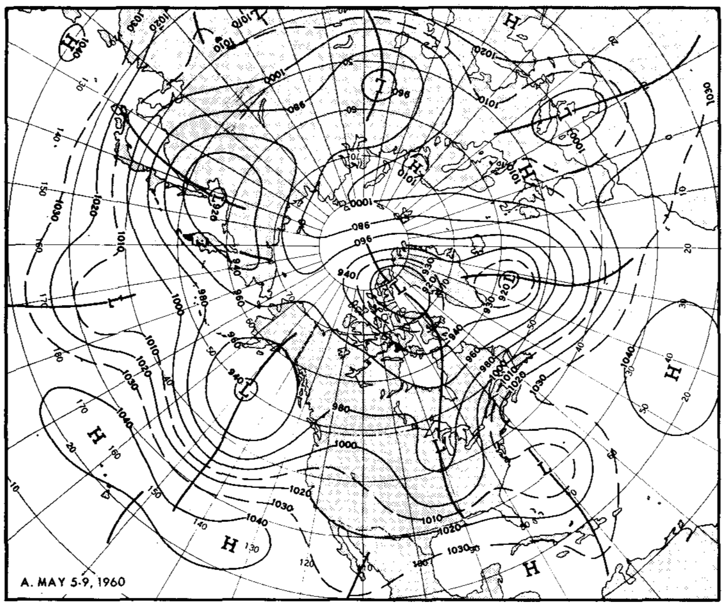
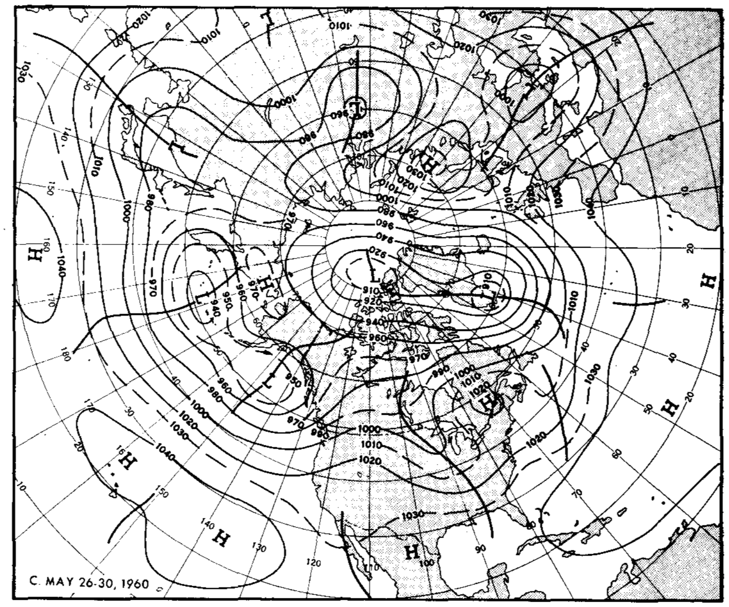


FIGURE 12.—Observed 5-day mean temperature classes over the United States for periods corresponding to those in figure 13.

time variation during May 1960 of the 5-day mean values of 700-mb. polar westerlies and sea level polar easterlies averaged over the western part of the Northern Hemisphere between 55° N. and 70° N. Clearly there were two complete index cycles which were closely related to positions of the sub-polar cells. As an example, note that when the cyclonic vortex occupied the Canadian Arctic





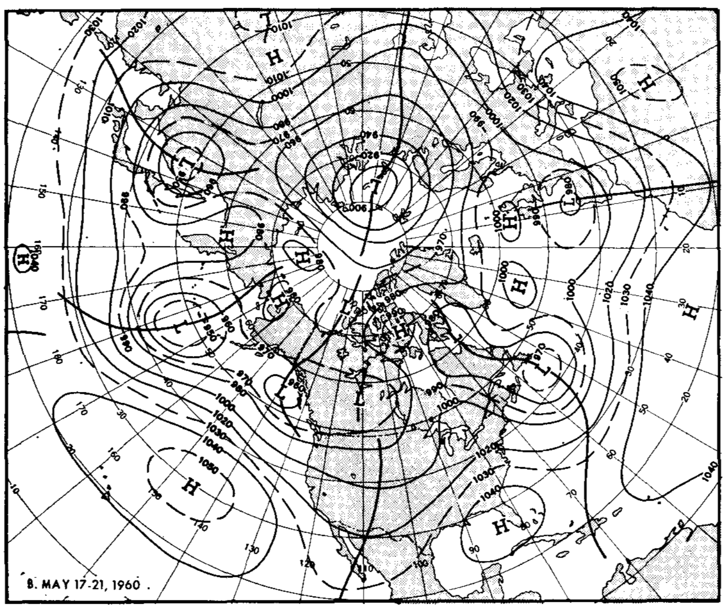


FIGURE 13.—5-day mean 700-mb. contours (tens of feet) for (A) May 5–9, (B) May 17–21, and (C) May 26–30, 1960. Recurrence of the circulation was an interesting feature of the month.

area on the 7th and 28th of May (fig. 9B), the polar westerlies were at a maximum and polar easterlies at a minimum (fig. 10), but the reverse was true when high pressure occupied the same area. The relation between position of the polar cells and the zonal circulation is further illustrated by figure 11, which shows the time-latitude variation of 5-day mean zonal wind speeds averaged over the Northern Hemisphere at 700 mb. The alternating periods of easterly and westerly circulation at the higher latitudes reflect the index cycles previously mentioned.

It is evident that a recurrence of approximately 3 weeks existed in the polar circulation. This was also true of the mid-latitude circulation patterns over much of the hemisphere and of the temperature patterns in the United States (figs. 12 and 13). Figure 13 shows the 5-day mean 700-mb. charts for the Northern Hemisphere for three selected periods. The similarity between the circulation patterns for May 5–9 and May 26–30 is quite apparent. Note in particular the low centers over central Asia, southern Europe, the North Atlantic, and Ellesmere Island. The patterns in North America were also similar, particularly with respect to the trough-ridge positions. The magnitude of this similarity is expressed statistically in table 4, which shows the correlation coefficients between the 700-mb. height anomaly patterns for selected periods along each 10° of latitude from 30° N. to 80° N. over the entire hemisphere, along with the overall pattern correlation. As might be expected, the patterns for May 5–9 and May 26–30 were very highly intercorrelated, especially at the higher latitudes.

On the other hand, the May 17–21 circulation, approximately midway between the two periods cited above, was quite different. While the May 5–9 and May 26–30 periods had strong ridges centered over Scandinavia, the May 17–21 circulation featured a deep sub-polar Low. Other major differences are apparent elsewhere over the hemisphere. Table 4 shows that the latitudinal correla-

TABLE 4.—*Correlation of 5-day mean 700-mb. height anomalies over the Northern Hemisphere between selected periods during May 1960*

Periods	Latitude (° N.)						Overall correlation
	80	70	60	50	40	30	
May 5–9 and May 26–30	0.94	0.96	0.69	0.36	0.27	0.30	0.67
May 5–9 and May 17–21	−.72	−.90	−.27	.34	−.41	.09	−.22
May 17–21 and May 26–30	−.86	−.81	−.24	.21	−.15	.30	−.04

tions between May 5–9 and May 17–21 were quite similar to those between May 17–21 and May 26–30. At higher latitudes both sets of correlations were very strongly negative.

In order to determine how well this circulation recurrence was reflected in the temperature patterns in the United States (fig. 12), a count was made of the number of stations (out of 100) whose temperature class either remained the same or differed by not more than one class. It was found that 75 percent of the stations satisfied this condition for the similar circulation patterns, May 5–9 and May 26–30. However, a count between May 17–21 and each of the two periods May 5–9 and May 26–30 gave percentages of only 53 and 69, respectively. Although other factors are involved, it would appear, then, that the temperature patterns in the United States were related, in part, to the concomitant circulation changes over the polar regions.

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U.S. GOVERNMENT PRINTING OFFICE: 1960